Laser transmitter for space-based water vapor lidar

Completed Technology Project (2017 - 2020)

Project Introduction

Water vapor (WV) lies at the heart of most key atmospheric processes. Humidity is essential for the development of severe weather, it influences, directly and indirectly through cloud formation, the planetary radiative balance, and it influences atmospheric dynamics, surface fluxes and soil moisture. Despite its central importance, research to date has not led to a universally accepted picture of the factors controlling WV amount, a solid understanding of the mechanisms by which it influences atmospheric processes, or even precise knowledge of its concentrations in many parts of the atmosphere. A future satellite-based WV Differential Absorption Lidar (DIAL) would revolutionize weather and climate research by providing high-resolution and accurate WV profiles with global coverage. Passive microwave and IR measurements are the backbone of weather and climate research but have significant limitations. Passive measurements are weighted toward the upper troposphere and hence have very little sensitivity near the surface where the majority of WV and its largest spatial and temporal gradients reside. Passive sounders also suffer from coarse vertical resolution and unknown biases resulting from aerosol and cloud contamination. The DIAL approach is self-calibrating, and its measurement uncertainties can be precisely quantified and traded by adapting the spatial resolution to the defined scientific objective. Furthermore, the DIAL approach can overcome one of the largest shortcomings of current passive measurements by adjusting the measurement sensitivity to near-surface atmosphere to capture the moisture variability above and through the boundary layer, in the presence of intervening cloud and aerosol layers in order to improve our understanding of fundamental mechanisms driving convection and cloud microphysics. Conventional WV DIAL lasers are inadequate for space-based operation as they are inefficient, complex, and have low average power, which limits precision and spatial resolution. We propose to build a WV DIAL laser transmitter to enable WV DIAL measurements throughout the troposphere from a space-based platform. The transmitter will probe an atmospheric WV absorption line near 816 nm, allowing for profile measurements of WV number density using the DIAL technique, and aerosol and cloud profiles using the backscatter lidar approach. As part of this effort, we will advance the TRL of the laser transmitter to lower the development time, risk, and cost of a future WV DIAL satellite instrument. The proposed laser will utilize thulium-based solid-state laser crystals, which offer the prospect of greatly improved efficiency, simplicity, and average-power scalability compared to conventional methods. Recent proof-of-principle demonstrations of Tm:LiYF4 (YLF) lasers highlight the promise of the proposed approach, provide laser physics understanding, and set a clear development path. The objective of this proposal is to develop Tm:YLF lasers with the energy per pulse (≥100 mJ), average power (≥10 W, 50 Hz double pulsed), efficiency (≥5%), and spectral control (≥ 99.9% spectral purity) needed for a space-based WV DIAL. The period of performance for the proposed effort is 3 years. Years 1 and 2 will focus on risk reduction where critical performance metrics will be

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Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Lead Organization:

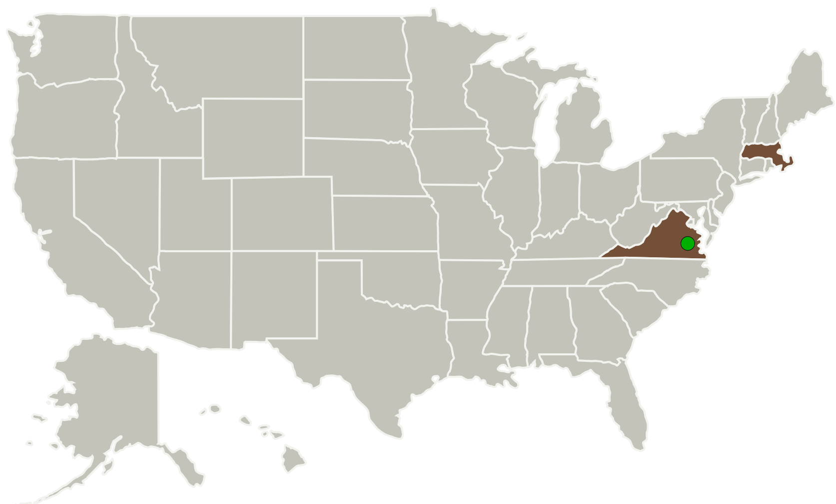
Massachusetts Institute of Technology (MIT)

Responsible Program:

Advanced Component Technology Program

demonstrated on a bench top breadboard. In year 3 we will design and build a brassboard laser compatible with the NASA Langley Research Center (LaRC) WV DIAL, High Altitude Lidar Observatory (HALO). We exit the program with a brassboard laser that has the performance of a space-based WV DIAL system and will be validated using HALO in a follow-on effort from high-altitude aircraft as a stepping stone to space. This technology has entry TRL-2 and a planned TRL-4 exit with a clear path to TRL-5 in a follow-on program by incorporation of the brassboard laser into HALO.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Massachusetts Institute of Technology(MIT)	Lead Organization	Academia	Cambridge, Massachusetts
Langley Research Center(LaRC)	Supporting Organization	NASA Center	Hampton, Virginia
Massachusetts Institute of Technology Lincoln Laboratory(MIT-LL)	Supporting Organization	R&D Center	Lexington, Massachusetts

Project Management

Program Director:

Pamela S Millar

Program Manager:

Amber E Emory

Principal Investigator:

Tso Yee Fan

Co-Investigators:

David M Pronchick
Steven Augst
Amin R Nehrir

Technology Areas

Primary:

- TX08 Sensors and Instruments
  └ TX08.1 Remote Sensing Instruments/Sensors
    └ TX08.1.5 Lasers

Target Destination

Earth

Primary U.S. Work Locations	
Massachusetts	Virginia